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Sustainable transition of socio-technological systems: How can Governance Network Research and Transition Theory contribute to the transition to biofuel for transportation?

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The paper suggests that the challenge of sustainability demands a shift of the attention of environmental planning and policy to the transition of socio-technological systems. Deliberate planning for sustainability then becomes a question of addressing governance structures of socio-technological systems, calling attention to how such governance structures emerge, stabilize and become dominant, which functions governance structures have to serve to become efficient, and how they can be made subject to deliberate and purposeful shaping and transition. Taking this approach, research in planning and policymaking for sustainability has to work with issues of understanding how actors and networks configure, requirements to effective networks and metagovernance of governance networks. Research within innovation systems, transition management and technology systems combined with planning and experimental activities provides both a theoretical and empirical body of knowledge of such governance processes. The paper presents these approaches and discusses how they can be used in relation to the process of developing bio-fuel systems for transportation.

Introduction

The challenge of sustainability has shifted the attention of environmental planning and policy to the transition of socio-technological systems[i], and has given rise to a new body of research addressing transition management (Kemp & Rotmans 2001, Kemp & Loorbach 2006) and an interest for the research in the development of technology systems (for example Jacobsson & Bergek 2004). This research has subscribed to a wide field of theoretical work on the shaping and development of technology and socio-technological systems. Important elements have been evolutionary and institutional economy, social construction of technology and innovation system (Geels 2004). On a general level the transition management approach has subscribed to a framework of reflexive modernisation, or more specific reflexive governance of socio-technical systems (Voß, J-P et al. 2006). Environmental planning has turned into a governance problem: how to stimulate and shape the configuration of the socio-technological systems and how to install a capacity of reflexivity in relation to environmental problems and sustainable development.

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This places a focus on how governance and networks develop in socio-technological systems[ii], and how metagovernance can influence such governance to integrate environmental considerations. Problems of governance, such as they have been addressed in governance theory, become a central issue. With a focus on *planning the transitions of systems*, there has naturally been a focus on some of the core questions in second generation governance network research: how actors and networks configure, requirements to effective network governance and metagovernance of governance networks.

The paper falls into four main parts:

- Sustainable transition of systems
- Governance and sustainable transition
- Bio-fuel - Governance of an emergent technology system
- Network governance research and transition analysis

I. Sustainable transition of systems

Environmental transition

Making environmental concern an integrated part of sector policies and business has from the early 90'ties been part of European environmental policy schemes and programs. Examples can be Dutch National environmental programs including programs on sustainable technology (Weaver et al. 2000, Kemp & Rotmans 2001) and the Danish product oriented programs (Remmen 2006). These programs all place the development of industrial production technology and in a wider perspective the development of production and consumption systems as a central part of environmental policy.

Studies of environmental innovations in enterprises and industries have revealed that such changes are embedded in and shaped by complex patterns of interaction of actors and institutions (Hansen et al. 2002, Holm & Stauning 2002). It points to the need of policy schemes and regulation addressing systemic capacity building in terms of an institutional reflexivity based on distributed capacity among actors (Søndergård et al. 2004, Rennings et al. 2004). A systemic approach implies a need of developing policies and programs stimulating and modulating the configurations of actors and network to obtain environmental changes – environmental policy has become a question of how to shape and transform governance of socio-technological system.

Sustainability and planning processes

The concept of sustainability adds a normative guiding perspective to transition of socio-technological systems. However, it is a concept open to interpretation by different actors and interests, a fact, which have led to criticism claiming that the concept is an empty phrase, and that it should be abandoned as a guiding concept in favour of more specific environmental and social goals. This has been strongly opposed by Voß & Kemp (2006). On the contrary, they regard sustainability as the major challenge of contemporary modernity, and in direct comparison with such concepts as democracy and welfare, which have been open concepts subject to interpretations and struggles in earlier stages of modernity; they see the problems of 'defining' sustainability as part of a reflexive modernity (Voß & Kemp 2006, Beck 2006).

They argue that the sustainability claim for '*a development that meet the needs of the present without compromising the ability of the future generations to meet their own needs*' (WCED 1987) have been generally accepted as a normative orientation (Voß & Kemp 2006). From their perspective sustainability establish a new problem framing, highlighting the interconnectedness and long-term and indirect effects of actions. Instead of seeing sustainability as a concept, which cannot be integrated in policy and planning processes, they claim that the plea for sustainable development, with its complexity, ambiguity of social goals and uncertainty of outcome, have strong implications for our policy and planning processes. *The concept of sustainability has brought with it recognition of the limits of rigid analysis and the inadequacy of policy approaches that aim at planning and achieving predetermined outcomes* (Voß & Kemp 2006:4).

The complexity of the plea for sustainability and the complexity of the system make it necessary to redefine the planning process. Voß et al. (2006:164) point to three important aspects, which makes traditional rational instrumental planning impossible:

a) *Potential transformation paths and effects of intervention are highly uncertain, because they are a result of complex interactions between social, technical and ecological processes which cannot be fully analysed and predicted*
b) *Sustainability goals remain ambivalent, because they are endogenous to transformation it self. Conflicts between objectives cannot be resolved scientifically or politically, once and for all*
c) *The power to shape transformation is distributed among many autonomous, yet interdependent actors without anyone having the power to control all others.*

This leads Voß et al. (2006:164) to forward an understanding of sustainable transition as a process of reflexive governance.

Transition of socio-technological systems

The understanding of technology as socially embedded implies that changes of technologies goes together with changes of actors, relations and institutions. A number of theoretical approaches, such as social construction of technology (SCOT) (Pinch & Bijker 1990) and actor network theory (ANT), such as neo-institutional theory, all have contributed to the understanding of how technology development relates to a concurrent configuration and stabilization of actors, networks and institutions (Geels 2004). More specifically, work with proactive technology assessment has discussed how such processes could be tailored to meet social ends (Kemp et al. 1998).

Socio-technological embeddedness implies a high degree of path dependency and rigidity, making it adequate to talk about socio-technological regimes. *Socio-technological regimes* can be defined as a dominant actor-network and institutions (Kemp & Loorbach 2006:108) with "*dominating practices, norms and shared assumptions, which structures the conduct of private and public actors*" (Kemp & Rotmans 2001:7). The regime forms norms and practices that frame processes of innovation and diffusion of technology. Shifts in regimes include changes in technology, user practices, regulation, industrial networks, knowledge, symbolic meaning. (Geels 2002). Normally regimes have a high degree of path dependency – incumbent actors and lock-in to established technologies and rationalities.

Based on this understanding of technology embedded in regimes, a multi-level model for technological change processes has been forwarded. Changes are perceived as a multi-level process (Rip & Kemp 1998, Geels 2002, 2004); an interplay of the development of *niches, regimes and socio-technical landscape*, where socio-technological landscapes includes such elements as material infrastructure, macro-economy, political culture and coalitions, social values, belief systems and paradigms, demography and nature, while niches are local domains, where non-standard technologies and new learning processes emerges. Transformation of regimes for sustainable development within this framework can be related to the development of niches either as bottom processes based on social movements (Smith 2003) or as a deliberate process of transition management (Kemp & Rotmans 2001).

This places a focus on the role of niches - how they develop in interplay with regimes and how they can be supported by deliberate actions. One approach is Strategic Niche Management understood as '*the creation, development and controlled phase out of protected spaces for the development and use of promising technologies by means of experimentation, with the aim of (1) learning about the desirability of the new technology and (2) enhancing the further development and the rate of application of the new technology*' (Kemp et. al 1998:187). Deliberate actions are perceived as a reflexive and constitutive process ' *The primary aims of strategic niche management are stimulating learning about problems, needs and possibilities of a technology, building actor networks, alignment of different interest to a goal, altering the expectations of different actors and fostering institution for adaptation*' (ibid, 191). Development of niches depends on how we succeed to develop and configure networks of actors and institutions in relation to the technologies

Berkhout et al. (2003) advocate for a more differentiated way of understanding regime changes, paying higher attention to specific context. They make a distinction between change processes based on 1) internal or external resources and with 2) low or high co-ordination, and propose four ideal types of change process dynamics: a. endogenous renewal (int./high), b) re-orientation of trajectories (int./high), c) emergent transformation (ext./low) and d) purposive transitions (high/low). Taking this approach, Berkhout et al. argue, that research in transition of socio-technological regimes should give much more attention to the function and dynamics of regimes (internal and in interplay with external context).

Technology systems

With a stronger focus on the process of developing new technologies Jacobsson et al. (2004) has introduced 'technology system' as an analytic entity[iii]. They define a technology system as (a) *network(s) of agents interacting in a specific technology area under a particular institutional infrastructure for the purpose of generating, diffusing and utilizing technology* (Jacobsson and Bergek 2004:817). Technology systems in this way are defined as a particular configuration of actors, networks and institutions (*norms and rules regulating the interaction of actors* (ibid)) – the constituent elements.

In their analytic framework Jacobsson et al. (Jacobsson & Bergek 2004, Bergek et al. 2005) identify seven essential functions, which have to be served by a technological system, namely a) creation and diffusion of knowledge, b) guidance of the direction of search among users and providers of technology, c) entrepreneurial experimentation, d) the formation of markets, e) legitimation, f) resource mobilisation such as capital and competences, g) creation of positive externalities (e.g. advantages of access to specialised goods and service providers, pooled labour markets and information flow). This functional approach both serves to define what should be included as part of the technology systems (all elements which influences on providing the functions, should be included) and as a benchmark for the maturity and effectivenss of the technology system related to specific (new or alternative) technologies.

In relation to the development of emergent alternative technologies (in relation to an established system) they make a distinction between the formative period and the market expansion. Both stages are considered important, but in particular the formation stage where configurations of actors, networks and institutions have to be shaped and the seven basic functions have to be provided and stabilised are seen as critical (see below, section III).

II. Governance and sustainable transition

In this section problems of governance are going to be treated in greater detail. In particular we address meta-governance perceived as governance activities aimed at changing governance structures in socio-technological regimes or of technology systems.

Governance and transition management

Socio-technological regimes are complex systems subject to attempts of steering by actors inside and outside the regimes; they are the collective – and contingent - outcome of the strategic choices and social interaction of many actors. It is systems that defy blueprint steering also in relation to a deliberate transition for sustainability, both due to the character of the system and due to the character of the challenge of sustainability. Voß & Kemp (2006) have summarised these problems of deliberate transformation[iv] in relation to the dynamic of the system, problems of goal formulation and strategy implementation – and have stated some requirements for reflexive governance (see Table 1)

Table 1: Strategy elements of reflexive governance (in relation to sustainability)

	Specific problem features	***Strategy requirements***
System analysis	*Co-evolution of heterogeneous elements across multiple scales (Society, technology, ecology)*	*Trans-disciplinary knowledge production*
	Uncertainty and ignorance about transformation dynamics and effects of intervention	*Experiments and adaptivity of strategies and institutions*
	Path dependence of structural change, high societal impact	*Anticipation of long-term systematic effects of measures*
Goal formulation	*Sustainability goals involve value trade-offs, are endogenous to transformation*	*Iterative participatory goal formulation*
Strategy implementation	*Capacities to influence transformation are distributed among actors*	*Interactive strategy development*

Source: Voß & Kemp 2006:18

Transition of socio-technological regimes for sustainability becomes a question of modulating the governance structures and dynamics of the regimes. The model of transition management elaborated in Dutch context (Kemp& Rotmans 2001, Kemp & Loorbach 2006) is an attempt to develop a framework of such a meta-governance. On a general level it subscribes to the presented understanding of reflexive governance,

Major elements of transition management are:
- An orientation to long-term transition goals (based on visions), development of learning and innovation programmes related to these goals,
- A focus on system innovation and experimentation/learning (create variety based on visions)
- System thinking in terms of a multi domain, a multi level and multi actor approach

- Opening up of policy processes to reduce dominance of vested interests (escape lock in)
- Processes based on participation and interaction between stakeholders

In short, transition management can been described as '*a forward-looking, adaptive, multi-actor governance aimed at long-term transformation processes that offer sustainability benefits*' (Kemp & Loorbach 2006:103).

A central instrument in turning transition management into operational policy and planning is the formation of a multi actor networks (transition arena) in relation to specific sectors (innovation systems) and transition goals, with the aim to establish new rationalities and capacities of the innovation system. In general terms the transition arena is conceived*" as a new institution for interaction can be considered a meta-instrument for transition management and facilitates interaction, knowledge exchange and learning between the actors*. (Kemp & Loorbach 2006:111). Major objectives of transition arenas are to define problem, establish transition visions and transition goals and to create public support and broadening the coalition.

The arena (or activity cluster) should form the basis of a reflexive governance process, where it in a cyclic way moves from stages of organizing multi-actor networks, developing (negotiating) sustainability visions and transition agendas, mobilizing actors, executing projects and experiments and evaluating, monitoring and learning. It should condition the process of bringing forward alternative (niche) technologies e.g. facilitate and modulate the generation of a variety of technology options and selection processes.

However, establishing such meta-governance processes as suggested by transition management has a number of inherent problems. To some extend they are related to specific problems of transition of socio-technological system in terms of the path dependencies which characterises such systems and with the unclear role of public policy

The first problem is how to identify and install actors in transition arenas (Kemp & Loorbach 2006). Who is in a privileged position to establish transition arenas, picking participants and condition the processes of the arenas? In the transition management approach there is a tendency to operate with the state as such a privileged actor and there are high expectation of the capacity of the state to manage both the formation of the transition arenas and establishing a framework of transition processes.

Transition arenas are always situated in specific contexts and are very often related to established technology systems. The problem of operating with transition arena as a privileged institution under such conditions is that there is a high risk that they are captured by incumbent player and subject to their strategic interests. Processes which were designed to open up established policy and technology trajectories and to create a variety of technology options risk to reproduce the established path (stick to less radical alternatives) or to pick 'suboptimal' technologies and development paths (Hisschemöller 2006).

Governance and technology systems

The value of the technology system approach[v] (Bergek et al 2005, Jacobsson & Bergek 2004) is that provides a method for assessing the functions served by the technological system; an assessment that is crucial for assessment of and development of governance and metagovernance of a system.

This framework provides a conceptual framework of analysing governance processes in the system (seen as processes related to the seven functions) and it provides a conceptual framework of analysing the effectiveness of the system.

The question is how they configure and how purposeful metagovernance can be exercised in formation periods and market expansion stages.

The formative stage of emergent technology systems – a stage often characterised by competing designs and uncertainty – may be of particular interest in a meta-governance perspective. In the formation process of the configuration of technology systems, they in particular pay attention to processes of initial markets, entry of enterprises and resources, institutional alignment and the formation of 'technology specific advocacy coalitions' (a policy network oriented towards achieving credibility and legitimacy of the technology in case).

Metagovernance should be perceived as the bulk of actions – by individual actors or policy institutions – directed towards to influence on these four processes or in general to influence how the seven functions are undertaken, e.g. specific actors, networks and institution constellations framing the creation and diffusion of knowledge, or framing the guidance of direction. Meta-governance both relates to influencing and promoting supportive mechanism related to the functional elements of the technology system (of emergent technologies) and initiatives designed for removing blocking mechanism (e.g. fragmented research hampering knowledge production and diffusion, uncertainties and lack of visions resulting in lack of direction).

Interplay with other governance processes

So far focus has been on the development (transition) of governance of the individual system. If we want to address the transition processes we have to include how they interact with other governance processes.

Governance processes within defined areas (regimes) have to be seen in context with governance processes taking place in other areas or on a more general level (Landscapes). … *new modes of governance must, in this respect similar to technology, be understood to be embedded in systemic contexts of more encompassing governance patterns which are structured by a specific configuration of social values, knowledge, institutions, technology and natural conditions. Governance innovation therefore needs to relate to this configuration of its context. And it must be acknowledged, again similar to technology, that governance innovation follows specific dynamics, which cannot easily be planned and controlled, but are highly contingent on the interaction of many actors and contextual developments* (Voß 2003:4).

Shifts in EU policy can be an example of such more encompassing governance patterns. The Lisbon process, making development of environmental solutions and technology an integrated part of strategies for competitiveness and globalization can illustrate this. Programs of building capacity for sustainability are now transformed into programs of development of technology platforms and clusters enabling the development of environmental technology and products for a global market (FORA 2006).

III. Biofuel for transport: an emerging technological system[2]

An example of a technological system is the emerging technological system of biofuels for transport in Denmark. This technological system is in its formative stage in Denmark. Actors, networks and institutions exist and a number of the core functions of a technological system are performed. We are interested in this technological system because of its environmental importance - even though it is too early to assess its potential in a sustainability perspective. The environmental aspects of biofuels are presently intensively debated among technical experts and policymakers.

Seen from the perspective of the Danish energy system biofuels for transport is a radical innovation which has to be established in an existing dominating technology system. The energy system is an integrated system with many path dependencies. The institutional framework is developed in relation to dominant discourses focusing on security of supplies, access to cheap energy and reliability. Technologies and infrastructure have developed during a long rang of time and the knowledge system has developed accordingly. Actors have been constructed and they constitute as well a stable industrial and a policy network. Alternative energy systems for example based on wind power are accepted but they are seen as niche production supplying marginal parts of the energy supply. It is difficult to establish a new discursive and industrial frame work for radical innovations because many of the relevant actors are embedded in the dominant technology system. Therefore transformation processes have to consider how to establish story lines that could be acceptable, trustworthy and appear necessary for actors in the energy system. At the same time is it important for the story lines to appeal to new actors that could contribute to a new dynamic in the energy system.

During recent years world production of biofuels have increase rapidly; in 2004 world production of ethanol was around 30 billion litres, approximately 2 % of global petrol use and it is set to increase with around 11% in 2005. Brazil is the world leading with about 30% of its petrol demand covered by biofuels, and the production is increasing rapidly in the US (EU Commission 2006a pp. 22, EIA 2004 pp. 11). The EU has formulated rather ambitious targets for the use of biofuels for transport: 2 % in 2005 and 5.75 % in 2010, but so far the level in 2005 was 1.4% at a maximum (based on announced targets). But many countries have formulated rather ambitious targets and policies (EU Commission 2006a). Germany and Sweden have during the last year pursued ambitious policies and achieved substantial growth in production and/or use of biofuels for transport (Segerborg-Fick 2006; Sauter 2006).

However, the future development of the technological system in Denmark is uncertain; the EU targets for use of biofuels in petroleum are not binding, and so far there has not been political support for making the institutional changes necessary for market formation in Denmark. Even if the indicative EU target was 2% for 2005, the Danish Government set the target to zero (Økonomi- and Erhvervsministeriet et.al. 2004). After heavy criticism the government announced an indicative target for 2006 on 0.1% and in spring 2006 that it will allocate 200 million DKKR over the next four years for the development of 2nd generation biofuel technology (Danish Government 2006 pp. 10). Finally in early October 2006 the Danish Prime Minister announced that the government

[2] This is a draft based on very preliminary empirical work, where elements might be missing and some of the descriptions of the system might not be entirely correct.

wanted to do *something* on energy supply and energy security (Rasmussen 2006), and a more detailed plan is expected in autumn 2006.

We delimit the technological system as the system producing biofuels for transport from biomass. The entire technological system thus includes both the production of biomass, the transformation of biomass into fuels for transport, the distribution of biofuels and the use of the fuels for transportation. In the short run the production of biomass and the distribution and use of biofuels links up to existing technological systems. Existing agricultural products and bi-products can be utilized as raw-material for the production of biofuels, even though in the long run other agricultural products as energy woods (willow) might be desirable. And biofuels can be mixed into traditional fuels, distributed through the existing distribution system and used in the ordinary cars with combustion motors, even though some minor adjustments of the fuel systems in cars might be warranted. The radical deviation from existing technology systems in the short run is in the transformation of biomass into biofuels. There are number of different methods for the production of biofuels (EIA 2004; EU Commission 2006a). In Denmark there is a limited production of biodiesel; the Danish company Emmelev A/S produces in the magnitude of 80.000 tons biodiesel from rape for export – mainly to Germany. However the potential in biodiesel in Denmark is relatively limited when it comes both to volume and environmental benefits (Felby 2006). The potential in ethanol produced form biomass is far higher. 1st generation processes are based on yeast fermentation of the immediately accessible sugar in the biomass, and basically the process is the same as for production of ethanol for consumption (alcoholics). 2nd generation processes via different processes, often using genetically modified enzymes, makes the sugar fixed in the cellulose fibre in the biomass accessible for the fermentation process, and thus increases the effectiveness and efficiency of the process considerably.

So far only 1st generation processes are running on a commercial scale in many different countries around the word (EU Commission 2006a), whereas is seems that many attempts to develop 2nd generation processes are ongoing, and a number of pilot plants are running.

The actors involved in Denmark are research institutions, big multinational companies, big energy companies and a number of smaller entrepreneurs. The actors in Denmark cooperate around a number of big projects

The Integrated Biomass Utilisation System (IBUS) is a bio refinery concept planned to be added on an existing biomass fired power plant utilizing a number of processes – amongst other 2nd generation bio-ethanol; and the plan is that the biomass on the complete installation shall contribute to the production of bioethanol for transport, food, animal fodder and electricity/heat. And the plan is that any kind of biomass can be used – be it agricultural waste, wood or organic household waste. The main partners in the project are DONG Energy in cooperation with researchers from The Royal Veterinary and Agricultural University and Risø National Laboratory. Presently a pilot plan utilising 2nd generation technology on straw is up and running (or more precisely in the process of being moved from Fynsværket to Skærbækværket due to Vattenfall's taking over of Fynsværket). It is planned to upscale the production from 1 t/hour to 4 t/hour and a decision process regarding the possible establishment of a full-scale bio refinery by a power plan is ongoing in DONG energy. The development and research has been supported by EU research funds (Nielsen 2006, Energistyrelsen 2005 pp. 22-24). However, if the framework conditions are not improved in Denmark, it is not likely that the development to full scale will take place in Denmark (Neilsen 2006, Felby 2006)

The Maxifuels project at the Technical University of Denmark is also a 2nd generation bio refinery concept. The process produces bioethanol, hydrogen, biogas and electricity/heat. The main partners are DTU, Novozymes and DONG Energy (that in June 2006 merged with the former Energy E2). A pilot plant was opened on September 13 2006 at DTU. The hope is that the pilot plant will pave the way for a demonstration plant. So far the main funding has come from the Danish energiforskningsprogram, Energinet and Novozymes (Energistyrelsen 2005 pp. 22-24, Danish Centre for Biofuels 2006, Skøtt 2006). According to Professor Birgitte Ahring the main problem for the project today is that they are running out of time. Due to lacking interest from the Danish state it took a long time to establish the pilot plant and they are now falling behind competing concepts in e.g. Canada, U.S., Spain and Sweden. Therefore they must establish a demonstration plant in 2007. According to the professor the problem is no longer money because today there are plenty of interested investors (Ingeniøren 20/10 2006).

Bio-energy Park in Toender is planned as an integrated bioethanol, biodiesel and biogas 1st generation plant with an investment at around 150 million Euro, to be placed near Tønder in Southern Jytland. The main actors involved in the project are local public authorities (Tønder Municipality, "Sønderjyllands udviklingsråd" and the länder government in Schleswig-Holstein) and a research network of biofuel researchers in Denmark and Germany. All the necessary permits from the authorities are in place for the energy park and so is the financing for the ethanol component of the energy park. However construction will not start before the Danish framework conditions are changed, so a market for bio-ethanol can develop in Denmark. If these conditions are not established within a relatively short time horizon the project will allegedly move to either Germany or Hungary (Nissen 2006 and personal comment 25/8 2006; Politiken 24/9 2006).

Further a feasibility study has been done for a bio-ethanol refinery in Kalundborg in connection with the existing Statoil oil refinery. That feasibility study was done in cooperation between LandboSjælland, Rambøll Danmark, JC Consult, Statoil, DLG and Kalundborgegnens Erhvervsråd. Statoil has announced that they intend to actually construct a bio-refinery in Kalundborg, and are presently negotiating with different investors (Erhvervsbladet 7/9 2006; Statoil, June 2006). It seems that the plan is to start as a 1st generation plant and later develop into a 2nd generation plant and that the construction plans aren't dependent on the improvement of the Danish framework conditions (Autobild 14-07-2006).

Danisco has also been considering reconstructing one of their sugar factories in Denmark into a bioethanol plant, but it seems it has been decided to develop the bioethanol production somewhere else in Europe (Politiken 24/9 2006, Danisco 2006).

Further a number of smaller players have developed 1st generation plants on the drawing board. For example Bioscan has developed a process that transforms different types of biomass waste into energy, manoeuvre and clean water. For some time it has been attempted to establish a plant on the Danish island Ærø, but due to problems with the local planning process (NYIMBY), and poor profitability due to the Danish framework conditions the project is so far put on a halt (Rasmussen, Paul Ejner, 2006)

And as mentioned above the only present commercial biofuel production in Denmark is at Emmelev AS (Simonsen 2006). But for example Novozymes already has a good business in producing enzymes for 1st generation processes in the US using corn (Lange 2006).

So far the technological system in Denmark is in the formative stage: a number of actors are involved that form different types of competing and supporting groups, and an institutional structure for the development of the network is in place.

Landscape changes

The technological system of biofuels for transport is embedded in and dependent on a wealth of factors in the general landscape; of especial importance are of course the socio-technological systems of transport and of energy production, distribution and consumption. Despite quite a lot of talk about modal shift in the transport system away from road transport and petrol consuming car, road transport and petrol demand has steadily been increasing during the last decades. During recent years especially two landscape changes have changed the attention paid to biofuels for transportation: increasing convergence of views on climate change and CO_2 emissions and renewed worries about the security of energy supply.

These issues have the attention of the highest level of policymaking in the EU, as illustrated by a statement by head of the EU commission Barroso on the meeting of the council of Europe in Mach 2006: *"We are in a new energy century, demand is rising, Europe's reserves are declining, there is underinvestment and the climate is changing* (BBC online march 8 2006, see also Council of the European Union (2006) pp. 14).

Below we will elaborate on two of the factors that have changed the landscape for the technology system of biofuels for transport: climate change and security of energy supply.

Climate change

That the burning fossil fuels might impact the energy balance of the planet has been acknowledged in more than a century, but for many years the issue was dormant on the agenda of environmental problems. But in the early eighties concern was growing and a World Meteorological Organisation conference in 1985 put the problem on the international agenda as a serious issue that needed consideration. Since then the issues has steadily been climbing up the agenda. The scientific evidence that climate change is indeed a serous problem have accumulated, and a recent attempt to conduct an authoritative review concluded that "Compared with the TAR[Third Assessment Reports], there is greater clarity and reduced uncertainty about the impacts of climate change across a wide range of systems, sectors and societies. In many cases the risks are more serious than previously thought" (Tirpak et.al. 2005). On the political front progress has been made too – although slowly. The UN Framework Convention on Climate Change was signed in 1992; in 1997 the Kyoto protocol was signed requiring the developed countries (annex 1 countries) to reduce their emissions with 5% in the period 2008-12 compared to 1990. After prolonged negotiations on hammering out the detailed rules and convincing amongst others Russia to ratify the protocol – after have been expected to die – finally went in to force in February 2005. In December 2005 the parties to both the convention and the protocol decided to lunch discussions about the period after 2012. Meanwhile the opinion is changing in the US, and the assessment is today that whatever president enters into office after 2008 the US will get a very different climate policy geared towards actually doing something. Thus the discussions about the next step in the climate regime are developing (see e.g. Blok et. al 2005).

Security of energy supply

The EU is dependent on import of energy and this dependency is expected to grow in the coming years. Today imported energy covers around 50% of EU's energy supply and if not the EU is capable of producing more energy itself that is expected to rise to 70% in 20-30 years (EU Commission 2006b pp. 3), and a huge part of that will probably come form more or less stable parts of the world. In 2004 58% of oil consumption was imported from Russia, the Middle East and North Africa and 24% of Gas production form Russia. Especially the demonstrated willingness of Russia to use its energy resources and the European dependence as a source of power has caused a lot of concern regarding the security of supply of energy in Europe.

Presently Denmark is self-supplying with energy. But the national oil production is expected to peak soon, and unless other sources of supply are developed Denmark will in a few decades from new be very dependent on imported energy.

Stabilising goal and configuring actors

Stabilising the objectives for both the energy supply in general, energy supply for the transport sector and for the development of the technological system of biofuels for transport is complicated as there are so many more or less conflicting objectives. Above we discussed two changes in the landscape that has changed the objectives for the technological system to some degree: the objectives of reducing emission of green house gases and the objective of developing a more secure supply of energy has clearly gained importance during recent years. But these two objectives coexist with, compete with or are complemented by other objectives such as a cheap supply of fuels, industrial policy, regional development and a row of environmental objectives as preservation of biodiversity, local air quality etc. The way these different objectives are prioritised varies between countries. For example an assessment is that the objectives behind the ambitious and expensive Swedish policy on biofuels is CO_2 reduction, security of supply and the EU biofuel directive, whereas at the EU level the priority of the objectives is slightly different: Rural development, agricultural policy, security of supply and CO_2 reductions (Segerborg-Fick 2006). In Denmark the tentative impressions is that the objectives are a combination of giving priority to CO_2 reductions, national production of bio-mass and not wanting to touch the Danish 'tax-stop' implying that changes is the tax- and levy-structure are very difficult.

However, no matter how the different political systems prioritise the objectives the different actors make there own assessment of global, European and national developments, and assess how they best pursue their interests. For some actors, like actors related to agriculture and forestry, biofuels for the transport sector is an opportunity that is obvious to pursue. Agricultural lobbying is ongoing both at the EU level and the national level for supporting the development of biofuels for transport, and regions depending on agriculture like the region around Tønder or Kalundborg give support to the development of biofuels projects in their area. Further companies with global markets, like Novozymes and Danisco pursue the development of their business the best they can.

IV Metagovernance of technological systems: assessing and optimizing the functions of technological systems

The concept of technological systems covers specific configurations of actors, networks and institutions. Several schools exist within the field of innovation theory with each their emphasis. During recent years attempts to integrate some of the major findings from the different schools have been undertaken under the concept of *functions of innovation systems* (Bergek et.al 2005; Jacobsson and Bergek 2004, Johnson no year).

1. *Knowledge development and diffusion*. Developing solutions to identified problems are a core function for innovation systems. Doing so requires different types of knowledge (e.g. scientific, technological, market) and knowledge from different sources (R&D, learning by doing etc.), and includes both the existing knowledge base, development of new knowledge and the capability to combine and integrate knowledge.

Developing solutions to how to produce ethanol from biomass and distribute is requires different types of knowledge. Fundamental research in e.g. how to make the sugar stored in cellulose accessible for ethanol production is developed at the involved research institutions The Royal Veterinary and Agricultural University (RVAV), Risø National Laboratory (Risoe) and the Technical University of Denmark. Fundamental and applied research in the production of enzymes has been provided by Novozymes and Danisco. The energy company DONG energy (formerly Elsam and Energy E2) has developed knowledge about system integration and energy efficiency. The patenting of the two 2nd generation process IBUS and Maxifuels indicates that knowledge have been developed.

2. *Influence on the direction of search.* The development of a technological system requires that firms and investors are attracted to the system, and that the system is capable of steering the direction of search. The fulfilment of the function as a combination of many factors, amongst others stabilisation of visions for the system and market expectations.

The two 2nd generation biofuel projects in Denmark both seems to have had a lot of focus on energy-efficiency, but it do require a more detailed investigation to assess the which degree the Danish technological system has influenced the direction of search, or whether the direction of search is attributable to the actors individual orientation towards the EU and global level.

3. *Entrepreneurial experimentation*. The development of technological systems are uncertain therefore continuous experimentation is crucial*;* therefore the number of experiments undertaken by entrepreneurs in the system and the variety of the experiments are an important function.

During recent years quite a number of actors have been attracted to the system, and a number of concept for the production of biofuels have been developed, but the number of real experiments actually undertaken have been limited – allegedly due to the poor framework condition in Denmark compared to other European countries.

4. *Market formation.* A technology system needs a market to develop. Market formation can normally be divided into three stages: nursing, bridging and mass markets. The nursing

markets are ‘learning space’ for the new technology. They can develop into bridging markets and finally mass markets.

So far the marked in Denmark is very limited. One big petrol company (Statoil) started on May 30 2006 the distribution of Bio95, petrol with 5% bio-ethanol added.

5. *Legitimating.* Legitimacy means social acceptance and compliance with relevant institutions.

Biofuels for transport in Denmark has so far been a controversial issue, and there have not been much support from the government for it. For example the Danish government in its explanation of its implementation of the EU-biofuels directive stated that “Altogether biofuels does probably not entail a major benefit for the environment” (“samlet set er biobrændstof næppe til store fordel for miljøet”) (Økonomi- og Erhvervsministeriet et.al. 2004 pp. 2). And, as described earlier, the targets for the Danish implementation was set to zero in 2005 and 0.1% in 2006. However the Danish policy is controversial. The EU-commission have twice sent ‘reasoned opinions’ to Denmark about Denmark not having fulfilled their obligations, and a row of actors are rather critical to the Danish position (Finansministeriet 2004) and have worked in concert to try to convince the Danish Energy Authority about the flaws in their position (Peter Nissen personal comment august 2006), and put pressure on the government. However, the situation in Denmark is rather open: the Energy Authority is allegedly adjusting its position, high hopes are attached to 2nd generaiton biofuels, a commission is working in the central ministration, and the government has promised to something ambitious about the Danish energy policy – so everybody is waiting.

Thus the preliminary investigations points towards that the actors in the emerging technological system is struggling for legitimacy, but are having difficulties due to a number of stable ‘story lines’: Societal steering of energy-supply is about CO_2, not security of supply and secondly the stable ‘story line’ that any enlarged agricultural production will harm the environment.

6. *Resource mobilization.* For a technological system to develop a number of resources are required, human capital, financial capital and what you could call ‘complementary assets’ which include any complementary resource needed in the technological system.

A lot of human capital and research and development capital has been engaged in the development of biofuels in Denmark. Presently it seems that the technological system in Denmark stands at something of a threshold. Several of the major competing development groups are considering to move their investment out of Denmark (Politiken 24/9 2006, Claus Felby personal comment; Peter Nissen personal comment), and the small scale plants all claim that without changed Danish framework conditions they cannot operate in Denmark. However, it is debatable whether that is a problem for the development of the global technology system, as long as the expertise is utilised outside Denmark. However, some of the Danish actors claim that the conditions in Denmark are unique and optimal for the development of biofuels (Claus Felby, personal comment; Lange 2006).

7. *Development of positive externalities or ‘free utilities’.* This function implies that when a technological system grows bigger and stronger a number of positive externalities develop: emergence of pooled labour force, emergence of specialized goods and service providers and information flow and spill-overs.

> So far the technological system is probably too weak to develop positive externalities. IT would require a more detailed analysis to assess the flow of information between the actors in the technological system.

Taken altogether the very preliminary investigation of the status of the technological system of biofuels in Denmark points toward a system that has been through a fruitful formative development and now is at the edge of either takeoff into a growth phase or stagnation in Denmark, depending on how the meta-governance of the technological system develops. It is difficult to assess the effectiveness of the governance *in* the technological system. That would require a much more detailed analysis of the relations between the different actors. Especially the conflict between the Danish Energy Authorities and most of the other actors over the usefulness of biofuels would be interesting to analyse in more detail. The very stable story line of the Danish Energy Authority that the criteria for assessing biofuels was price of contribution to CO_2 reduction and that the basis for calculating this is the biofuels made form wheat in Denmark.

As the discussion about the stabilisation of goals demonstrated stabilizing goals is of crucial importance for the possibility for performing meta-governance. Whether framework conditions that allows the Danish system to take-off should be established or not depends amongst others on

- The prioritization between objectives related to climate change, security of energy supply and industrial policy
- The assessment of the environmental effectiveness of the processes developed in Denmark,
- The assessment of their competitiveness with processes developed in other countries and the strengths of the actor groupings around the different concepts to develop business models.
- The impact on other prioritised objectives as constant tax revenue from energy tax and a cost-effective environmental policy.
- A suitable 'package' of instruments can be established.

This is a complicated discussion. It would for example be worth analysing whether the spending of 1.3 billion Swedish krones (approx. 150 million Euros) per year on different types of tax reductions for biofuels that have resulted in a rapid development of distribution and use of (mainly) imported biofuels in Sweden (Segerborg-Fick 2006) is an efficient spending of public money.

In the Transition Management literature it has been suggested that the establishment of 'Transition Arenas' is a prerequisite for managing transformation processes; these arenas can make the above described types of assessment and transform them into meta-governance. However, even if the case of biofuels for transport in Denmark clearly demonstrates the importance of meta-governance and the need for meta-governance designed purposefully in relation to prioritized societal goals, it also demonstrates the importance for having processes that are open for many types of actors – and for groups of actors with different assessments than the prevailing ones.

V. Governance Network research and transition analysis

Governance network research and transition theory share a problematic about actor networks and their ability to exchange resources and coordinate autonomous actors strategies based on institutional norms and rules. Theories about the function of socio-technological systems and technology systems are relevant in order to understand path-dependencies and the functions that have to be handled in a dynamic technology system. The questions asked by the new generation of network research are very valuable to qualify the understanding of how networks in the borderland of the political and industrial system can restrain or support the establishment of new technology systems capable of developing more sustainable practices. The indefiniteness of future technology systems implies that governance and networks is the most effective way to establish more sustainable systems. On the other hand, path-dependencies of socio-technological technological systems points to the importance of metagovernance to establish the room for the formation of identities and actions.

Different types of Governance Network research can improve our understanding of the dynamics of industrial networks.

Technology systems theory gives us a departure from a somewhat functionalistic understanding of the forming of network as a result of growing differentiation and complexity. An important aspect is the understanding that the different functions in a technological system are embedded in practices, knowledge systems and infrastructure. Deliberate reconfiguration of technology systems is therefore often a sticky process. Network theory emphasizes the importance of the construction of a discursive and institutional framework for network governance. This is in line with earlier studies of the importance of the ecological modernisation discourse and its institutionalisation in different sectors of industry (Søndergård et al, 2004).

Likewise we have a focus on strategic games between independent actors in order to coordinate and at the same time develop the identities and capacities of actors. Governance Network research focuses in this respect on the mobilization, inclusion and construction of network actors. This is a very important perspective because transition often depends of new actors from other sectors of society that can be invoked and thereby be a part of the network. An example from our case study is the integration and potential conflicts of agriculture as a part of the energy sector. Also policy coordination through deliberation, power struggles and conflict resolution is important in order to establish network and governance.

Success and failure of governance network in socio technological systems is in our perspective a result of the ability to change the institutional frame work as a result of institutional reflexivity and learning processes in order to establish norms and rules that facilitates as well positive as negative coordination. It is to some degree inspired by different types of Governance network research analyses of effective network governance.

The metagovernance of networks in socio technological systems is often a hands off incentive steering but dialogue with especially governmentality theory can inspire analysis of the important dimension of the construction of rooms for development of identities and actions.

Future research

The idea in this paper has been to sketch a research program. Our prime interest is to analyze how government and actors in industry, research and development and civil society can contribute to the establishment and success of networks in socio-technological systems contributing to more sustainable production and consumption systems. A theoretical framing combining Governance Network Research, Transition Theory and Technology Systems Theory is expected to be fruitful in the analyses of specific transformation processes.

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[i] 'Socio-technological system' is here used as broad term to designate a number of different system approaches to transition of technology. In transition theory system approaches range from a concept of socio-ecological systems used by Voß/Kemp (2006), as the most encompassing concept, to the more specific and delimited concept of technology systems, which has been used by Jacobsson/Bergek (2005). In between we have concept of socio-technical systems (Voß 2004), socio-technological systems and regimes (used by Kemp (2001), Kemp/Loorbach (2006) in relation with their multi level model) or technological regimes (Kemp/Schot/Hoogma 1998, Smith 2003). Within social construction of technology socio-technical systems has been used as concept (Pinch/Bijker 1990).

[ii] Taking this approach we claim that socio-technological system move from being primarily governed by market forces to being in still greater extent subject to social and political interest - move from market to policy. Innovation is seen as a possible response to societal problems – and in this perspective we can talk about desirable innovation, and consequently a desire for directed innovations (see UKERC 2006). The demand of sustainable development reinforces this process. This is making it necessary to discuss how we may develop democratic network governance in relation to socio-technical systems and the way meta-governance can be developed to structure and give direction to the process of innovation and technology development. We both want to understand how such governance structures evolve, and we want to understand how they can be subject to purposeful (directed) meta-governance. Integrated in this is the question of how the perception of 'desirable innovations' is constituted in these processes – both the intended and emerging processes.

[iii] Jacobsson has stated that there are no contradictions in the 'three level approach' (Kemp & Rotmans 2001) and his 'technology system approach'. Both approaches examine the question of how to get from technical niches to socio-technological regimes (UKREC 2006). The approach forwarded by Jacobsson, however, can be seen as a subset to the regime-based approaches, given the more close attention to technology and innovation and less attention to the broader social-cultural context (integrated part of the 'regime' approach).

[iv] The problems of governance for sustainability resemble the general problems of intelligent change by political institutions described by Marc and Olsen in their book on democratic governance: 1) ignorance: uncertainties about the future and the casual structure of experience, 2) conflicts: inconsistencies in preferences and interests, 3) ambiguity: Lack of clarity , instability and endogeneity in preferences and interests. (March & Olsen, 1995, cited from Kemp & Loorbach, 2003)

[v] The technology system approach relates to a number of different approaches all with a strong attention to innovation, new technologies and functional patterns constituted by the structural components actors, network and institutions. In the latest works Bergek et al. (2005) operate with the concept of sectoral innovation system (SIS) paying a close attention to the innovation processes (including elements from the traditional innovation system theory) as they are structured with sectors. On other occasions they have operated with the concept of Technology Innovation System (TIS), still giving high attention to innovation systems, but with a closer look at individual technologies (The sectoral energy system consists of many TIS). The system can also be related to individual knowledge fields or products (product groups)(Bergek et al. 2005). In all these approaches their analytic approach is based on an examination of the dynamics of the structural components (actors, network and institutions), of the dynamics of the structural patterns and an examination of driving and blocking mechanisms (endogenous and exogenous).